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COMPLETE SPECIFICATION

FLOW METER AND METHOD FOR FLOW MEASUREMENT OF FLOWABLE MATERIALS

We, HER MAJESTY THE QUEEN in right of New Zealand, of DSIR Industrial Development, 24 Balfour Street, Auckland, New Zealand

do hereby declare the invention for which we pray that a Patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:

The invention comprises a flow meter and method for measuring the flow rate of a flow of particulate material.

Techniques and apparatus for measuring the flow rates of liquids are not necessarily applicable to flow measurement of particulate materials which will flow or can be caused to flow, such as powdered or granular materials, for example. Where such materials are conveyed, processed, or packaged or the like it is often desired to monitor the flow rate of the materials. Various apparatus and techniques for flow rate measurement with such materials are known.

The present invention provides an improved or at least alternative apparatus and method.

In broad terms the invention may be said to comprise a flow meter for measuring the flow rate of a particulate material, comprising a chamber through which the flow of material can pass, at least one outlet aperture through a wall of the chamber of known dimension(s) across the flow and of a height such that the height of the material flow through the outlet aperture from the chamber will not reach the full height of the aperture over the range of flow rates to be measured, and means for determining by reference to the weight of material in the chamber the flow rate of the material.

Preferably the outlet aperture of the apparatus is of a substantially constant and relatively narrow width over its

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height, so as to be in the form of a slit or slot for example. Other forms of outlet aperture may however be employed and it is not essential that the dimension across the aperture be constant over the height of the aperture, as will be described. It is also possible that the outlet "aperture", rather than comprising a single slit or slot or the like, could consist of a series of smaller holes or openings spaced heightwise in the wall of the chamber and the term "outlet aperture" in this specification is to be understood accordingly. The series of holes or openings need not be in the same vertical plane.

The height of the outlet aperture is such that the height of the material flow through the outlet aperture will not reach the full height of the aperture over the range of flow rates to be measured. The outlet aperture may be described as an "open" aperture. The top of the aperture does not, under normal flow conditions, limit the height of the flow of material from the aperture. For example, where the chamber in the wall of which the aperture is formed is a volume having a closed base and open at its top, the aperture may be a slit extending the full height of the side wall of the chamber. In other arrangements the aperture or slit could be closed at its top edge but the height of the aperture would then be chosen in relation to the flow rates expected to be encountered such that the height of the flow of material passing through the aperture would not in practice reach the full height of the aperture itself, so that for all intents and purposes the aperture may be regarded as an "open" aperture.

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The flow rate of a particulate material through such an open aperture can be correlated to the height of the flow of material through the aperture. Where the aperture is a slit or slot or the like which is of constant width over its height, and the slit or slot is relatively narrow in width, the flow rate of material through the slit approaches linear proportionality to the height of the material flow through the slit. Thus, the instantaneous flow rate of material may be determined by reference to the height at any instant of the flow of material through the outlet slit of the flow meter. In one form of flow meter of the invention the outlet aperture is a slit of constant width and the chamber in the side wall of which the slit is formed defines an interior volume of constant cross-sectional area through the height of the volume. The height of the material flow through the slit will thus be proportional to the volume of material within the chamber at any instant, which will in turn be related to the weight of material in the chamber at any instant. The height of the material flow through the slit at any instant may thus be determined by reference to the weight of the material in the chamber of the apparatus. When the flow rate of material under measurement through the apparatus and outlet slit is relatively high, the height of the material flow through the slit will be high and the volume of material in the

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chamber behind the slit will be high, so that the weight of material within the chamber will be relatively high. Conversely, when the flow rate of material under measurement through the apparatus is relatively low, the height of the material flow through the slit will be relatively low, so that the weight of material within the chamber behind the slit will be low. An electronic weighing and processing stage may be employed for monitoring the weight of material in the apparatus and determining therefrom the instantaneous flow rate of the material.

As stated, the slit need not be of constant width across the slit and for slits or outlet apertures of non-constant width a correlation between the height of the material flow through the slit or aperture and the material flow rate may still be found in any case.

The outlet aperture preferably extends vertically, but it is possible for the aperture to be tipped either sideways or forward or rearwardly to some extent, as will be further described.

There may be provided more than a single outlet aperture from the chamber through which the flow of material passes, as will be further described.

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The invention also encompasses a method for measuring the flow rate of a particulate material, comprising the steps of causing the material to pass through at least one outlet aperture in the wall of a chamber of known dimension(s) across the flow and of a height such that the material flow passing through the outlet aperture will not reach the full height of the aperture over the range of flow rates to be measured, and determining by reference to the weight of material in the chamber the flow rate of the material.

The invention will be further described with reference to the accompanying drawings, by way of example and without intending to limit the scope of the invention. In the drawings:

Fig. 1 is a schematic side view of one form of experimental apparatus of the invention,

Fig. 2 is a front view in the direction of arrow A in Fig. 1 of the first experimental apparatus,

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Fig. 3 is an enlarged view of a part of the apparatus of Figs 1 and 2,

Figs 4 and 5, and Fig. 6 illustrate two examples of other shapes of outlet apertures that may be employed, and an outlet aperture which is tipped relative to the vertical, respectively,

Fig. 7 is a schematic cross-sectional side view of a further form of apparatus of the invention,

Fig. 8 shows a part of the apparatus of Fig. 7 comprising the outlet apertures,

Figs 9 to 13 illustrate with reference to the apparatus of Fig. 8 examples of further shapes and configurations of outlet apertures that may be employed, and

Fig. 14 is a cross-sectional side view of a third form of apparatus of the invention.

Figs 1 to 3 show one form of apparatus of the invention. Reference numeral 1 indicates a vessel defining an internal chamber 2 through which the flowing particulate material, the flow rate of which is to be measured, passes. In the example shown the chamber 2 is of a constant and rectangular cross-section across the height of the chamber, so that in this example the volume of material 3 within the chamber 2 at any

instant will be proportional to the height h of the material therein (see Fig. 3).

An outlet aperture in the form of a vertical slit 4 (see Fig. 2) extends through the side wall of the vessel 1 as shown to form an outlet from the chamber 2. The slit is an open slit in that it extends to the top edge 1a of the vessel and in this example the slit 4 is of constant width over the height of the slit. Material flowing through the measuring apparatus passes firstly through a feed container 5 and from an outlet 6 of the feed container 5 into the measuring chamber 2. A deflector 7 serves to disperse incoming material from the feed container 5 as shown. Material indicated at 3 passing through the measuring chamber during operation of the flow meter will flow from the slit 4. As the flow rate of material into the chamber 2 increases, so will the height of the material flow passing from the slit 4 from the chamber 2. It has been found in practice that the height h (see Fig. 3) of the material flow 3a from the slit 4 is proportional to the rate of flow of material through the apparatus.

The height of the material flow through the slit 4 is determined by monitoring the weight of material within the chamber 2. In the experimental apparatus shown in Figs 1 to 3 the vessel 1 is supported on an electronic balance 8 so that the weight of material within the measuring chamber at any instant may be monitored. In a practical apparatus other weight determining means such as a load cell or load cells would be

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employed and could be associated with, for example, a microprocessor arranged to calculate and display, print, or pass to a process control system, for example, the flow rate of the material, the running mean flow rate, or the like as desired.

The arrangement of feed container 5 and outlet 6 has been employed as shown to enable calibration of the experimental apparatus described and other arrangements a feed hopper, if required for any particular application, may be of a different form. It is envisaged that in some cases a deflector such as the deflector 7 or something equivalent would however be required.

In the apparatus of Figs 1 to 3 the chamber 2 is of square cross sectional shape but other shapes of chamber such as circular or multi-sided chamber volumes could alternatively be employed. The chamber is of constant cross-section over the height of the container but the invention is not limited to such an arrangement and a chamber volume of changing cross-sectional area over its height could be employed. The slit 4 is a single, narrow slit of constant width over its height but as indicated previously the slit could be a wider slot of constant width or the outlet aperture could be on non-constant width. In all cases a correlation between the height of the material flow through the outlet aperture and the material flow rate may be found. The correlation may not be linear, but it is within the capability of modern microprocessor control equipment to deal

with other than linear proportionality arrangements which may offer some advantage for particular applications.

Figs 4 and 5 illustrate two other shapes of outlet apertures and Fig. 6 illustrates an outlet aperture which is tipped relative to the vertical. In all of Figs 4, 5 and 6 reference numeral 10 indicates a chamber which is functionally equivalent to the chamber 2 in the apparatus of Figs 1 to 3. In Fig. 4 the outlet aperture 11 is a slit which extends at an angle as shown. The slit is of a constant width over the length of the slit, but need not be so. The height of the material flow from the slit may still be correlated to the flow rate of material measured by the apparatus. In Fig. 5 the slit 12 is not of a constant width over the height of the slit but is in the form of an extended triangular slit, the width of which increases over the height of the slit. Again, the flow rate of material from the slit may be correlated to the height of the material flow so that even with slits shaped as shown the flow rate of a particulate material may be determined. The aperture shape of Fig. 5 might be employed where increased resolution is required for low flow rates and, vice versa, an angular outlet aperture of decreasing width over its height might be employed where greater resolution is required at higher flow rates.

The outlet apertures such as the slit or other shape of aperture need not extend vertically as in Fig. 3. The aperture could be "tipped forward" as shown in Fig. 6 for example, and a correlation between the height of the material flow from the slit and the flow rate may still be found.

Similarly, the outlet aperture or slit may be tipped rearwardly (not shown).

As stated previously, apparatus with multiple slits or other outlet apertures from the chamber 2 or equivalent are possible. Fig. 7 shows another form of apparatus of the invention. Reference numeral 13 in Fig. 7 indicates a part which performs the same function as the vessel 1 of the apparatus of Figs 1 to 3, defining an internal chamber 14 through which the flow of material, the flow rate of which is to be measured, passes. The part 13 is supported on a shaft 15 from the base 16 of the apparatus, through a load cell 17 so that the load cell will be sensitive to the weight of material within the container 13 at any time.

The part 13 is mounted within a generally cylindrical body 18 of the apparatus, having an entry for material at 19 and an exit for material in the form of an outlet chute 20. In use the flow of material enters the apparatus in the direction of arrow C in Fig. 7, and exits the apparatus from the chute 20 in the direction of arrow D. Within the body of the apparatus above the part 13 is provided a funnel member 21.

The part 13 is shown separately from the rest of the apparatus in Fig. 8. It is cylindrical (although other shapes could be employed as indicated previously) and comprises multiple outlet apertures in the form of a number of vertical slits 22 through the wall of the container 13, spaced about the

container as shown. Material flowing through the apparatus, the flow rate of which is to be measured, flows into the funnel 21 and from the funnel into the chamber 14, and from the outlet slits 22 of the chamber 13 to the bottom of the apparatus and from the chute 20.

Where multiple outlet slits or apertures are used, it is preferred to employ means for causing the flow of material from the chamber to be substantially evenly distributed between the multiple outlet apertures. In the apparatus of Figs 7 and 8 a conical centre piece 23 (see Fig. 8) is provided within the chamber 14 as shown, to assist in even distribution of the material over all the outlet slits 22, and to promote free draining of the measuring chamber when the flow of material stops.

Figs 9 to 13 show other shapes and configurations of outlet apertures in a part 13 for the apparatus of Fig. 7. In Fig. 9 the outlet apertures 22 are triangular in shape with the apex of each triangular aperture lowermost, as shown. This configuration has the advantage of maintaining accuracy at low flow rates, whilst allowing relatively higher flows to also be measured.

In Fig. 10 the measuring chamber has outlet apertures 22 which are triangular with the apex of each triangular aperture uppermost, as shown. This configuration provides increased accuracy at high flow rates.

In Fig. 11 the measuring chamber has outlet apertures 22 of an approximate I shape as shown, which provides for higher accuracy for mid range flows relative to lower or higher flow rates.

In Fig. 12, partitions 24 are are provided across the chamber between adjacent outlet slits. Each partition 24 extends from the base of one slit upwardly at an angle away from the slit as indicated in phantom outline, towards a mid point between the slit and its adjacent slit. This arrangement encourages free draining of the measuring chamber and prevents clogging of particles of material in the base of the chamber on either side of each slit.

Fig. 13 shows a similar arrangement where a small wedge shaped insert 25 is provided between adjacent outlet slits 22, to again encourage free draining and prevent clogging. In Fig. 13 a part of the exterior wall of the container 13 is shown cut away.

A further form of apparatus of the invention is shown in Fig. 14 in cross-sectional side view. The apparatus comprises a part 27 which in this example is generally cylindrical in shape and open at its top which has a conical base 27a, and the interior of which forms a measuring chamber 28. The part 27 is suspended within an outer container or jacket of the apparatus, comprising a central section 29 which may be cylindrically shaped and truncated cone shaped upper and

lower sections 30 and 31. The central section 29 and the upper and lower parts 30 and 31 are fixed together by flanges 33. They may be dis-assembled for cleaning or adjustment of the apparatus.

The apparatus is connected into a pipe in which particulate material, the flow rate of which to be measured is flowing, by flanges on the upper and lower sections 30 and 31 which connect to corresponding flanges provided on the piping 34 and 35 as indicated at 36. The direction of flow of material from the piping through the apparatus is indicated by arrows D.

The part 27 comprising the measuring chamber is mounted in position within the outer jacket by an arrangement of load cells for indicating the weight of the measuring chamber and its contents, and supporting wires. In the arrangement shown the part 27 is connected to the outer jacket through load beams 37 which are attached to lugs 38 fixed to inside surface of the central section 29 part of the container vessel and to corresponding lugs 39 suitably fixed to or fashioned on the wall of the part 27 defining the weighing chamber. The electronic input and output to and from each load beam is via a cable 40 as shown. For clarity, only one load beam arrangement is shown in the drawing.

Horizontal wires 41, only one of which is shown for clarity, maintain the measuring chamber in position. Each of the wires is attached at one end to the measuring chamber and at

the other end to a tensioning screw 42 which threads through the wall of the outer jacket or in some other suitable arrangement. Preferably three such wire arrangements equally spaced about the measuring chamber are used at the level shown in Fig. 14, and additional wires could also be used in a plane higher up the weighing chamber, in for example the same place as that of the load cells or load beams.

An outlet aperture in the form of a slot 43 is provided. Preferably three slots equidistantly spaced about the measuring chamber 27 are provided. A preferred method of enabling adjustment of the size of the outlet aperture is to form the same in a removable frame 44 and to attach the frame 44 over an oversized opening in the wall of the measuring chamber using screws or bolts or the like. A gasket (not shown) may be used to ensure that there is no space between the frame and the weighing vessel wall, so leakage does not occur.

In this form of the apparatus a drain hole 45 is provided in the conical base of the measuring chamber which is especially useful in conditions where good hygiene is important to ensure that material does not build up in the base of the measuring chamber. The apparatus may be calibrated to take into account the flow of material through the drain hole.

The apparatus of the invention is suitable for use with free flowing materials but might also be employed with more cohesive particulate materials, and by suitable choice of the

sizes and dimensions of and angles in the apparatus and of the slit or other outlet aperture dimensions, and/or with the assistance of sound waves, and/or vibration, and/or passage of an aerating stream of gas through the material, or other suitable means, such more cohesive materials may be caused to flow through the apparatus.

The invention provides a flow meter and method for measuring the flow rate of a free flowing material which enables a relatively high degree of accuracy but which is at the same time relatively robust and simple in operation. The foregoing describes the invention. Alterations and modifications as will be obvious to those skilled in the art are intended to be incorporated within the scope hereof as defined in the following claims.

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WHAT WE CLAIM IS:

1. A flow meter for measuring the flow rate of a particulate material, comprising:

a chamber through which a flow of particulate material can pass,

at least one outlet aperture through a wall of the chamber of known dimension(s) across the flow and of a height such that the height of the material flow through the outlet aperture(s) from the chamber will not reach the full height of the aperture(s) over the range of flow rates to be measured, and

means for determining by reference to the weight of material in the chamber the flow rate of the material.

2. A flow meter as claimed in claim 1, wherein the outlet aperture(s) is/are of a substantially constant width across the outlet aperture(s) over the height of the aperture(s).

3. A flow meter as claimed in claim 2, wherein the outlet aperture(s) is/are in the form of a slit or slot.

4. A flow meter as claimed in any one of the preceding claims, wherein the outlet aperture(s) extend vertically.

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5. A flow meter as claimed in any one of the preceding claims, comprising multiple outlet apertures.

6. A flow meter as claimed in claim 5, wherein the chamber comprises means within the chamber for causing the flow of material from the chamber to be substantially evenly distributed between said multiple outlet apertures.

7. A flow meter as claimed in any one of the preceding claims, wherein the chamber is supported by one or more load indicating means for indicating the weight of the material in the chamber at any instant.

8. A flow meter as claimed in any one of the preceding claims wherein the chamber is positioned or supported within an outer container or jacket arranged to be connected in-line to a conduit through which the material, the flow of which is to be measured, is flowing.

9. A method for measuring the flow rate of a particulate material, comprising the steps of

causing the particulate material to pass through at least one outlet aperture in the wall of a chamber of known dimension(s) across the flow and of a height such that the material flow through the outlet aperture(s) from the chamber

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will not reach the full height of the aperture(s) over the range of flow rates to be measured, and

determining by reference to the weight of material in the chamber the flow rate of the material.

10. A flow meter for measuring the flow rate of a particulate solid material, substantially as herein described with reference to any one or more of the accompanying drawings.

11. A method for measuring the flow rate of a particulate solid material, substantially as herein described.

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per:

ATTORNEYS FOR THE APPLICANT

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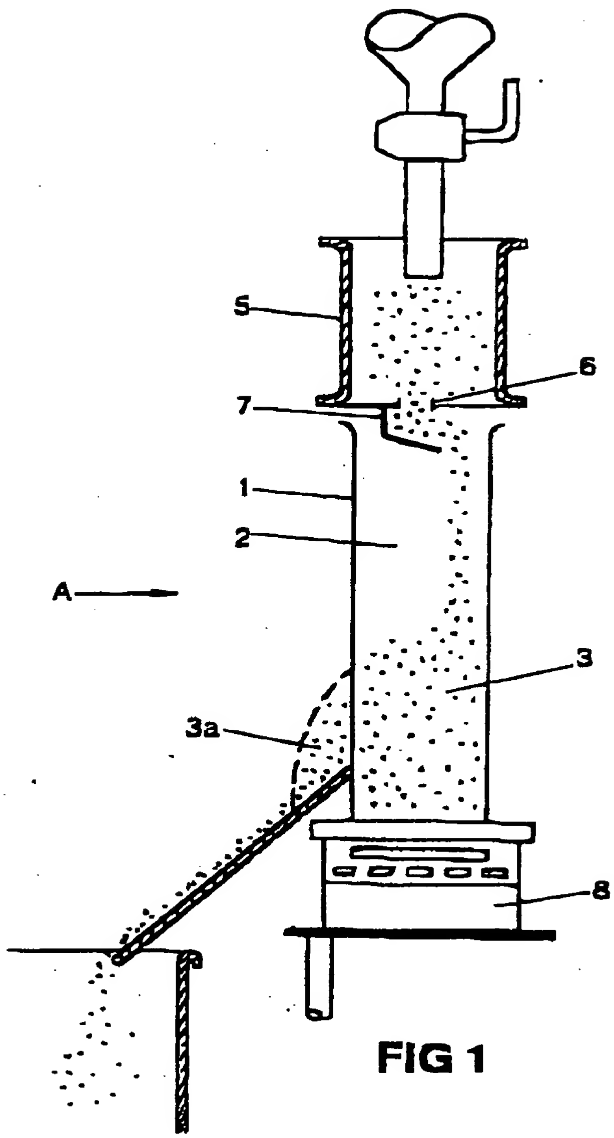

FIG 1

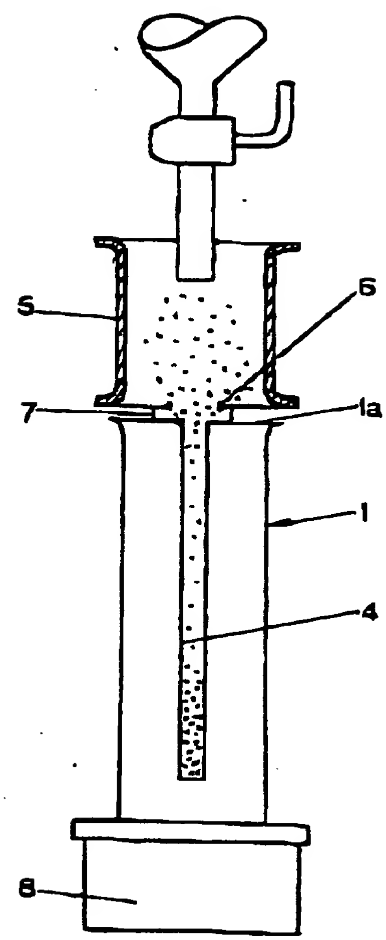

FIG 2

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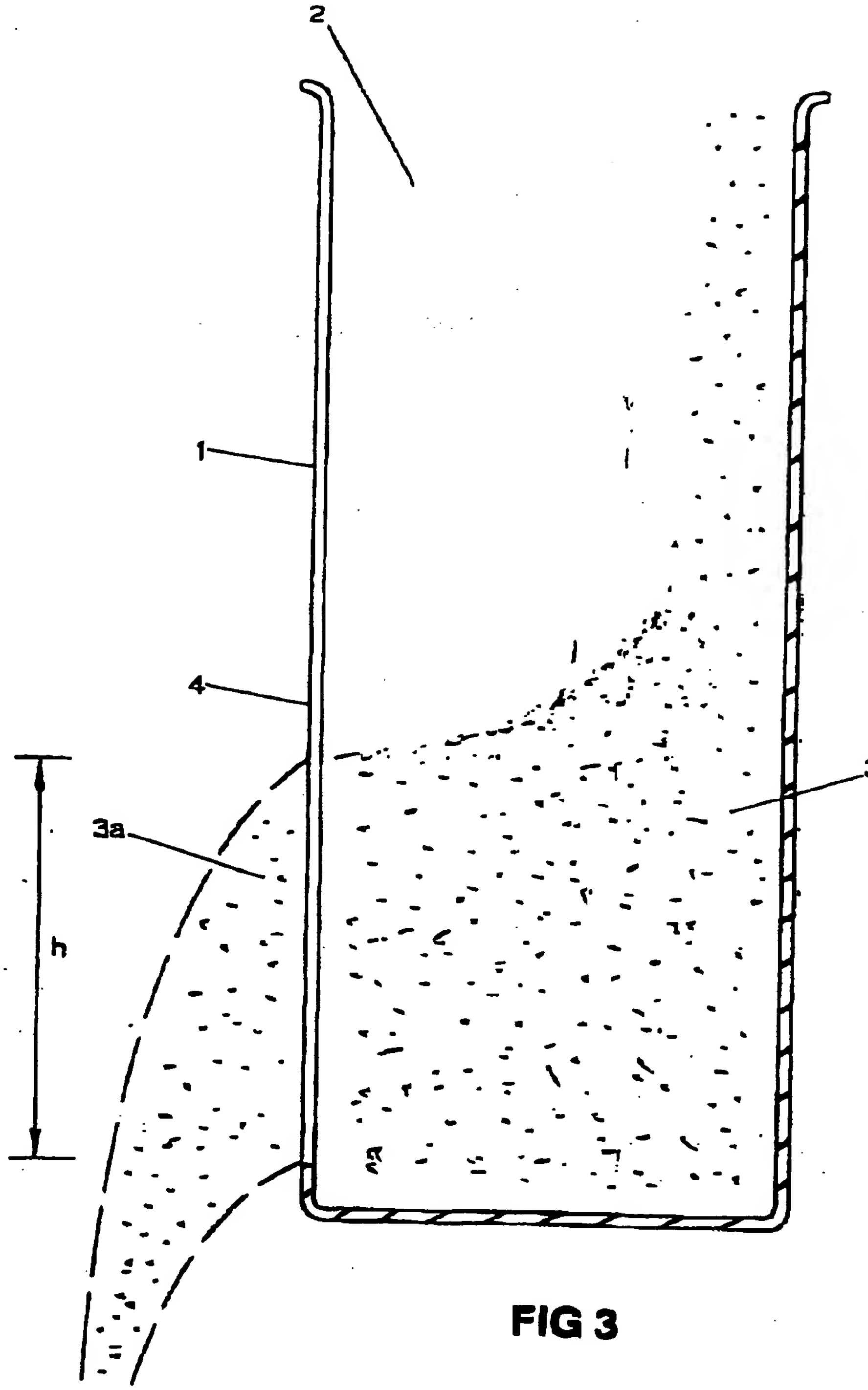

FIG 3

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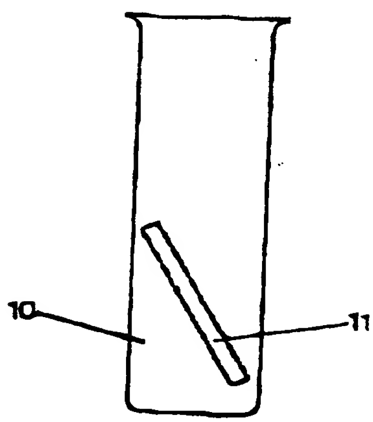

FIG 4

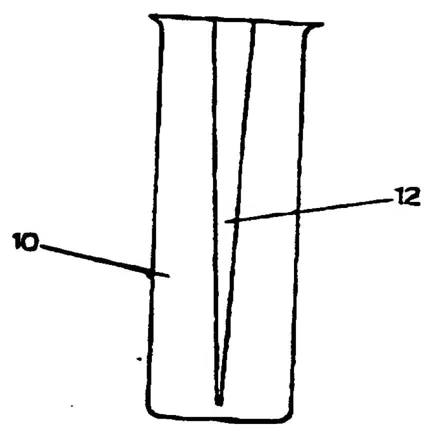

FIG 5

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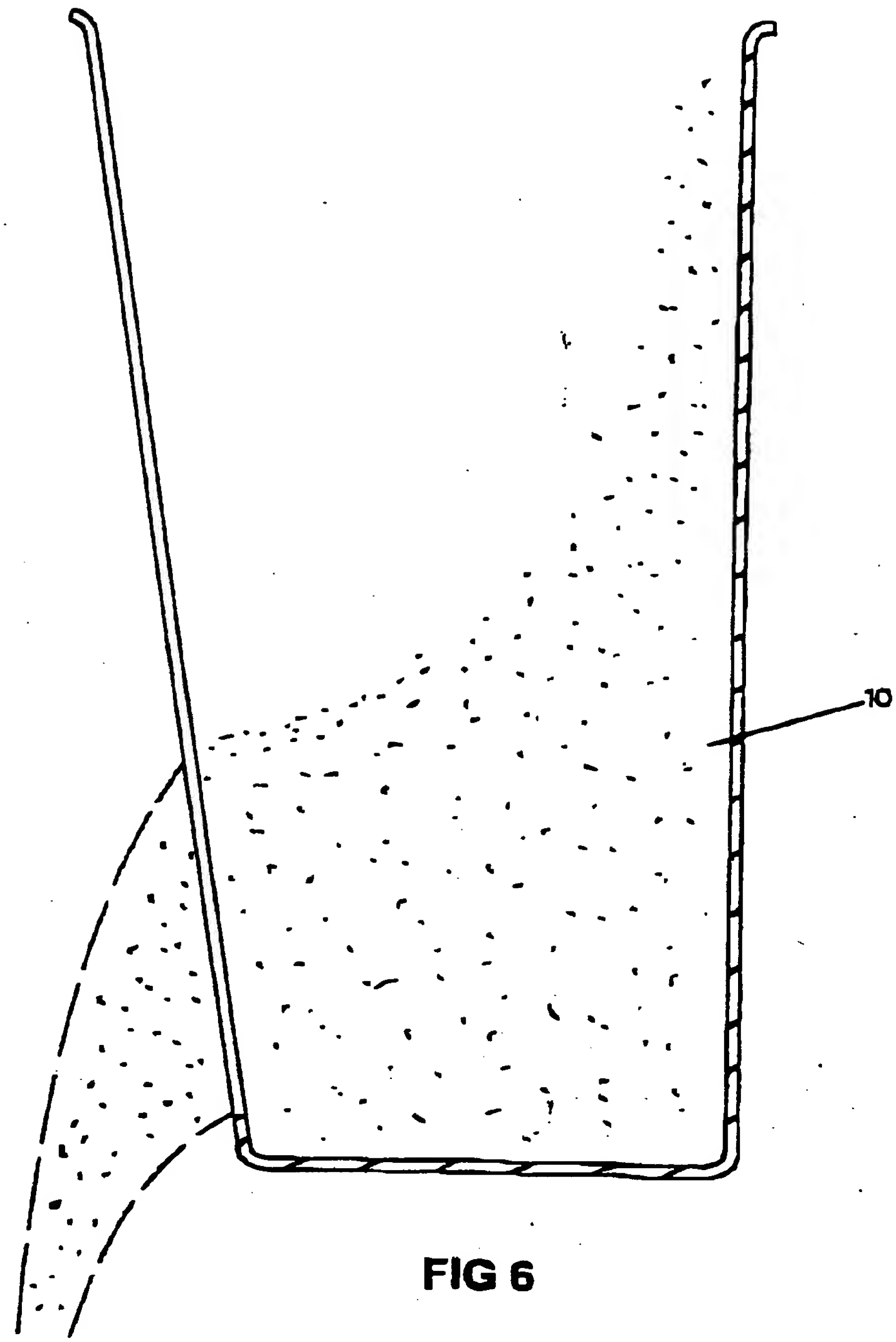

FIG 6

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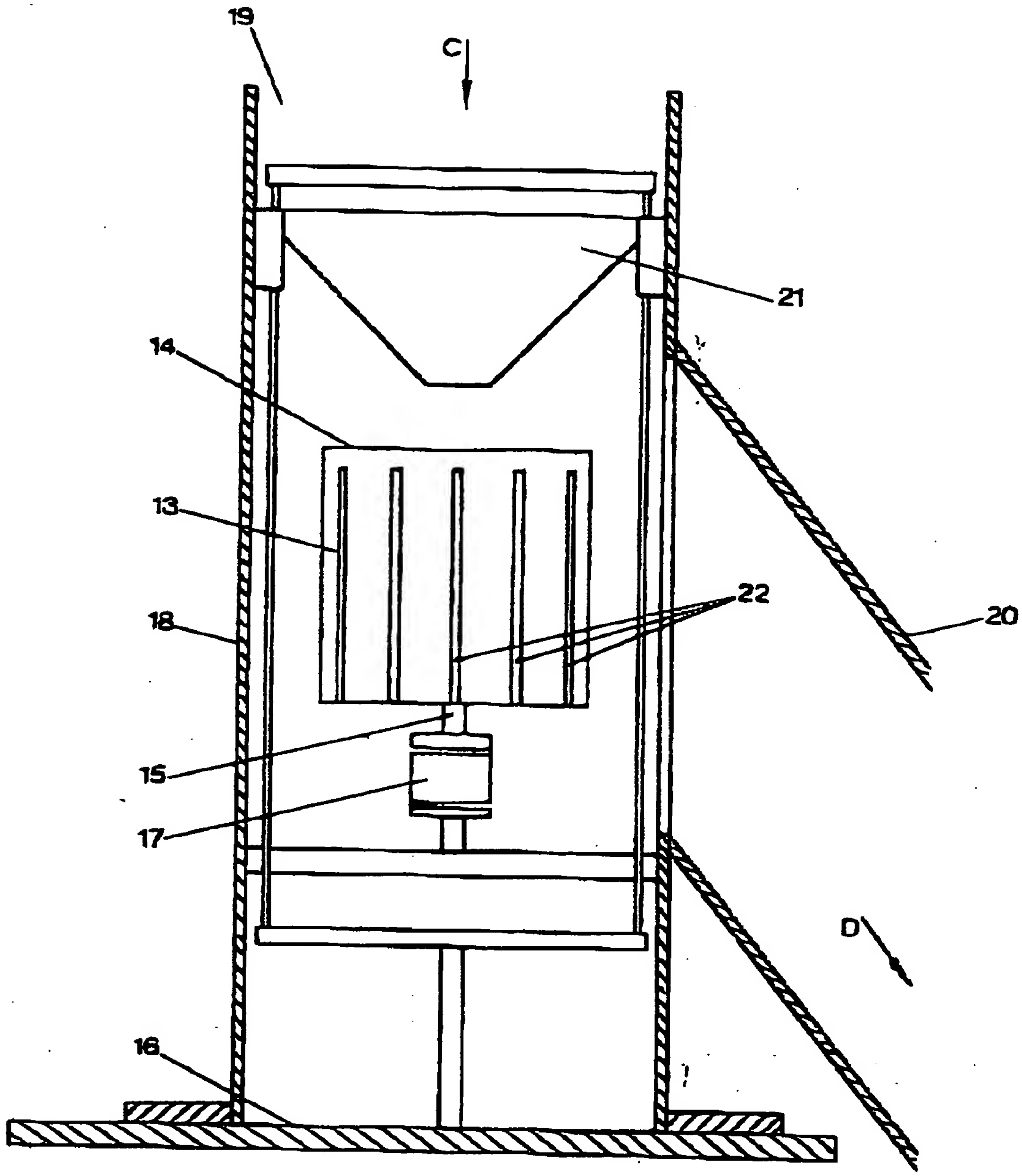

FIG 7

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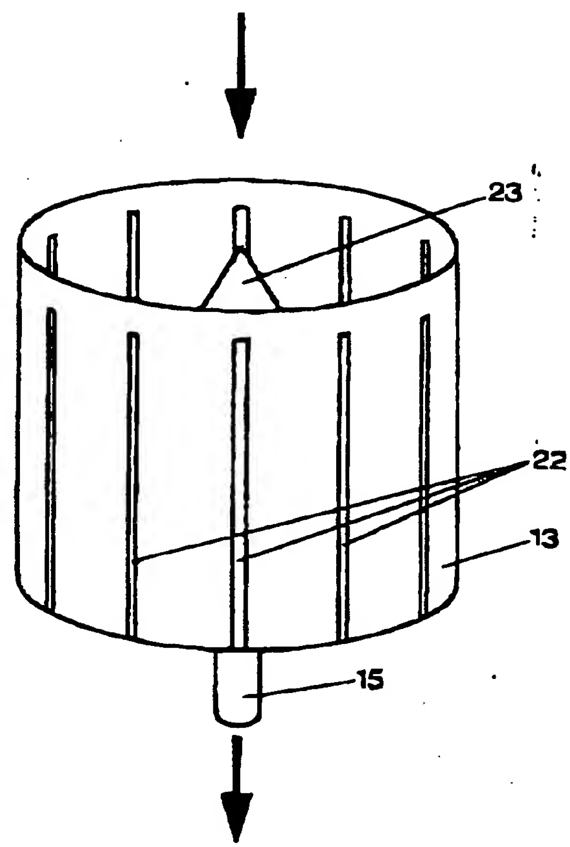

FIG 8

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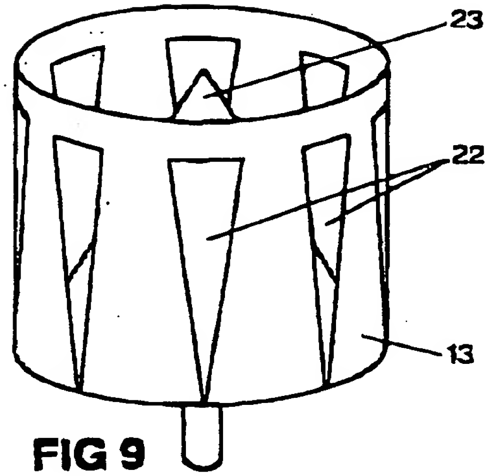

FIG 9

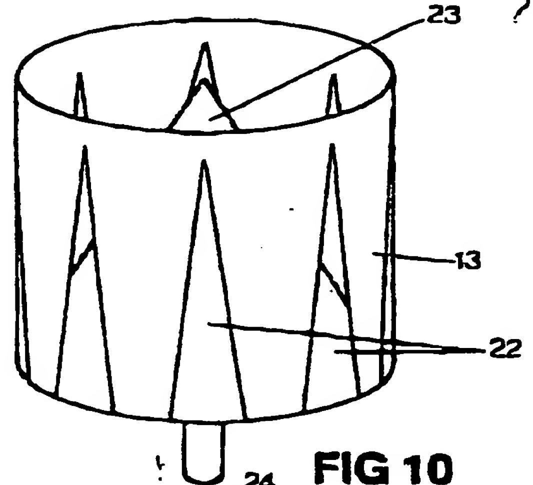

FIG 10

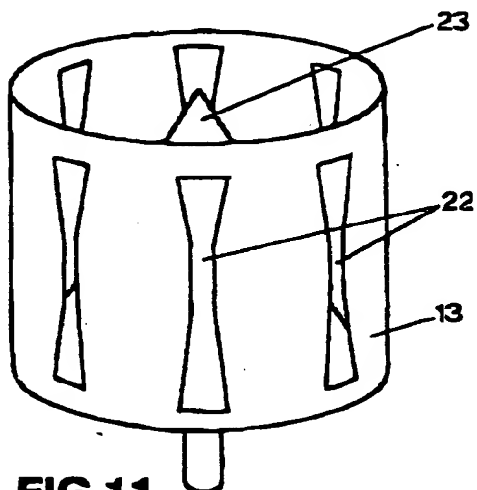

FIG 11

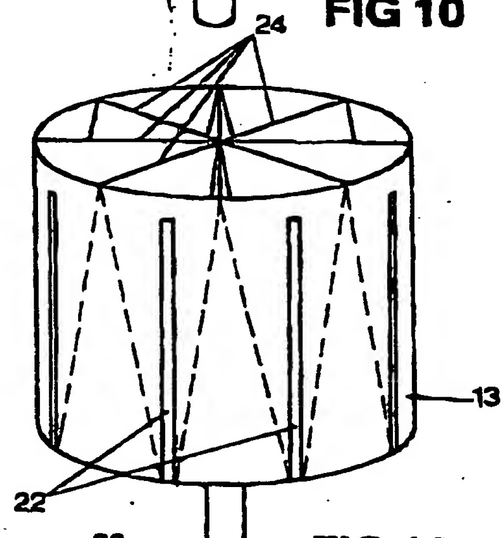

FIG 12

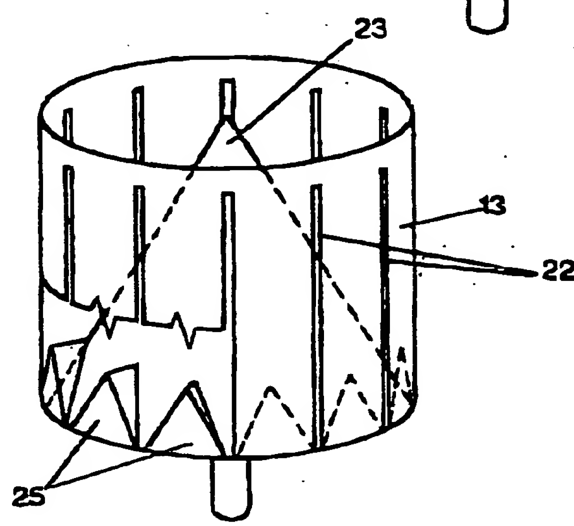

FIG 13

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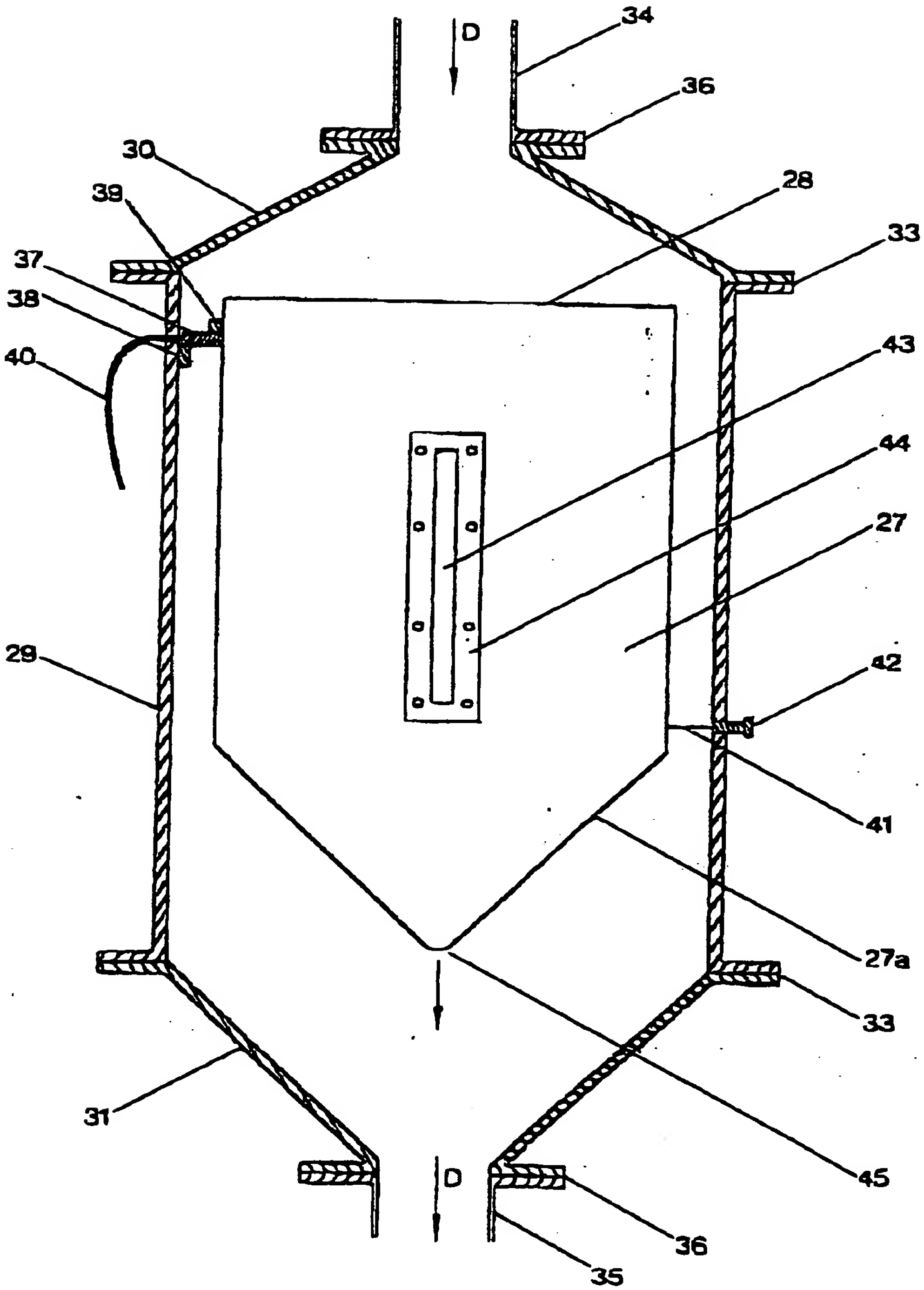

FIG 14

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